Scanning Our Past

Electrical Engineering Hall of Fame: Reginald A. Fessenden

In 1921, the Institute of Radio Engineers (IRE) selected the inventor–engineer Reginald A. Fessenden (Fig. 1) as the fourth recipient of its Medal of Honor. He had become known for his early and persistent advocacy of continuous-wave radio as opposed to the damped-spark system developed by Marconi. Fessenden conducted a public demonstration of radio broadcasting of voice and music in December 1906. He also made important contributions to underwater communication and echo detection. He was a prolific inventor who received approximately 300 patents during his career for inventions including an electrolytic radio detector, a radio alternator, and the heterodyne method of radio reception.

I. From Quebec to West Orange

The son of an Episcopal minister, Reginald Fessenden was born in East Bolton, QC, Canada. He spent one year as a student at the De Veaux Military School in New York State and then attended the Trinity College School, Port Hope, ON, Canada, from 1877 to 1880. Subsequently, he went to Bishop's College, Lennoxville, QC, although he did not complete the requirements for a degree. From 1884 to 1886, Fessenden taught at the Whitney Institute in Bermuda. He then accepted an offer of a job as assistant tester for Edison's power company in New York City. After a few months, he transferred to Edison's new laboratory at West Orange, NJ, where he had access to an excellent technical library and the best available test instruments and shop facilities. He worked closely with Arthur E. Kennelly on various projects involving chemistry and electricity for about three years, gaining experience with the Edisonian research methodology. A staff reduction at the West Orange laboratory cost Fessenden his job. He worked briefly for a Westinghouse affiliate and then joined the Stanley Electric Company, Pittfield, MA, where he worked on ac transformers and motors for about a year. During this period, the company sent him to England, where he collected information on British power technology and visited the famed Cavendish Laboratory at Cambridge University, Cambridge, U.K.

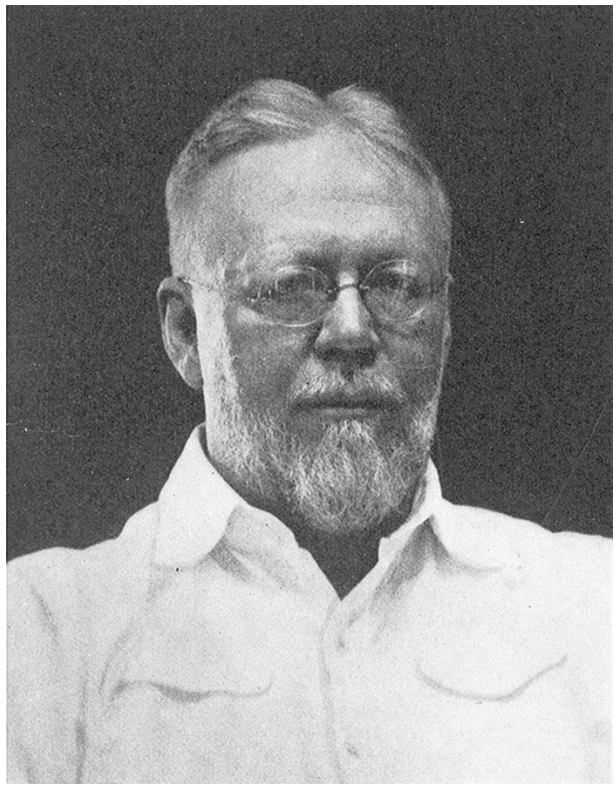

Fig. 1. Reginald A. Fessenden in his later years. (From the *Proceedings of the IRE*, vol. 20, no. 10, Oct. 1932, frontispiece.)

II. Instructor and Inventor

Soon after his return from England, Fessenden accepted an invitation to teach engineering at Purdue University, West Lafayette, IN, where he lectured on electrical theory and practice and set up a laboratory. After one year at Purdue, he joined the faculty at the Western University of Pennsylvania (later the University of Pittsburgh), having been recommended by George Westinghouse, who also agreed to pay half his salary. He remained there for seven years, during which time he and some of his students began to experiment with Hertzian waves. Fessenden also dabbled in theoretical physics and proposed what he called the "electrostatic doublet theory" as part of an attempt to link molecular theory to the macro properties of materials such as elasticity, tensile strength, and cohesion. This culminated in a paper published in the *Physical Review* in 1900 concerning theories of

Digital Object Identifier 10.1109/JPROC.2004.835353

0018-9219/04$20.00 © 2004 IEEE

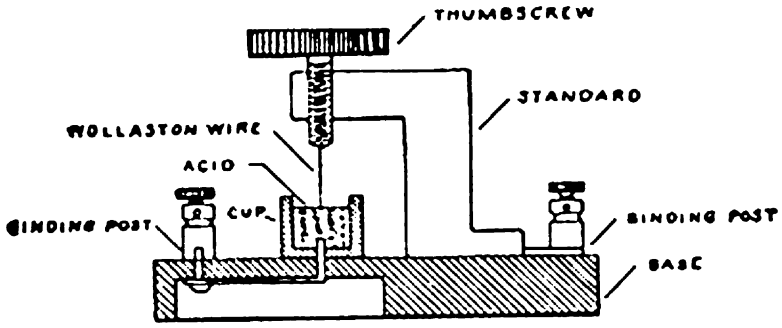

Fig. 2. Drawing of the electrolytic detector indicating the main components. (Courtesy IEEE History Center, Piscataway, NJ.)

matter, electricity, and ether. During his tenure at Pittsburgh, Fessenden gradually became disenchanted with the performance of spark-gas apparatus and erratic coherer wave detectors and began to search for better alternatives. He filed for his first radio patent in December 1899 just after he discussed the current state of wireless telegraphy at a meeting of the American Institute of Electrical Engineers (AIEE) in November 1899.

III. Experimental Wireless Station

Fessenden ended his academic career in 1900 to accept a contract with the U.S. Weather Bureau, which hoped to establish a network of wireless stations along the East Coast. Such a network would facilitate the collection of weather data from remote locations and the transmission of storm warnings to ships at sea. Fessenden soon set up an experimental wireless station at Roanoke Island, NC, and began testing some of his ideas to improve the Marconi apparatus. One of his first inventions was called a barretter (from a French word for exchanger) and was intended to replace the coherer wave detector. The key element of the barretter was a so-called Wollaston wire consisting of a platinum core with a silver coating. Fessenden modified the wire by etching the silver from a short segment of the wire using nitric acid and then enclosing the etched portion in a glass or metal bulb. He connected the barretter in series with a local battery and a telephone receiver. A wireless signal from a receiving antenna was found to cause a sufficient change in the resistance of the barretter to produce a sound in the receiving telephone. Unlike the coherer, it did not require tapping to restore its sensitivity, although it was subject to burn out if the signal were too strong. It proved less sensitive than later electrolytic and crystal detectors but continued to be used in laboratory measurements.

Fessenden's "liquid barretter," which became generally known as the electrolytic detector (Fig. 2), greatly enhanced sensitivity. This device used a pointed platinum electrode which was adjusted by a micrometer to just contact a liquid electrolyte such as a 20% nitric acid solution. The platinum point might have a diameter as small as one or two ten-thousandths of an inch for maximum sensitivity. In its application to wave detection, the liquid cell produced rectification of induced alternating currents. It proved to be an effective device, although it was rather difficult to maintain the proper adjustment on ships. Fessenden applied for patents on both versions of the barretter in June 1902 and May 1903.

IV. Heterodyne Receiver Concept

The heterodyne receiver was another of Fessenden's contributions to radio engineering. His idea required a local generator of high-frequency waves which would mix with a received signal. Provided the two signals differed in frequency by a frequency in the audible range, a telegraphic or telephone message could be heard in a headset. Although it was an ingenious concept, the heterodyne's benefits were not fully realized until the advent of vacuum-tube oscillators after about 1912. It was only then that Fessenden's patent, which he received in August 1902, became a valuable asset.

V. Early Wireless Voice Transmissions

Fessenden experimented with speech transmission by wireless during the fall of 1900 using a mechanical spark interrupter to produce an estimated 10 000 sparks/s. By utilizing a carbon microphone in the antenna circuit, he managed to transmit voice between two stations about 1 mi apart, although the quality was poor. This seems to have convinced him that a continuous-wave generator such as a radio alternator would be needed for successful radio telephony. Before he could obtain a radio alternator, a dispute with Weather Bureau officials resulted in the termination of his contract in August 1902.

VI. National Electric Signaling Company (NESCO)

In November 1902, Fessenden secured financial backing from two Pittsburgh investment bankers, Thomas H. Given and Hay Walker, to form a wireless company known as the National Electric Signaling Company (NESCO). Fessenden saw this as an opportunity to continue a search for a practical continuous-wave transmitter, although his investors probably were more interested in finding a buyer for his existing system. He began by installing a new experimental station in Brant Rock, MA (Fig. 3), where he could test a radio alternator he had ordered from the General Electric Company (GE). He had been granted a fundamental patent on the radio alternator in August 1902 and, lacking the facilities to build

Fig. 3. Fessenden is shown seated (center) with his technical team at Brant Rock, MA. (Courtesy IEEE History Center, Piscataway, NJ.)

one himself, turned to GE. The well-known GE engineer Charles P. Steinmetz agreed to undertake the design of an alternator capable of producing 10 kHz. The machine was completed and delivered to Brant Rock in March 1903. Steinmetz had used a fairly conventional design with coils on a rotating armature which limited the rotor speed in order to prevent disintegration of the windings.

Fessenden soon asked GE to attempt to produce an alternator for higher frequency and power. This time the design assignment was given to a young GE engineer, E. F. W. Alexanderson. To enable greater rotor speeds, he changed to the use of an inductor generator using steel rotors without windings. At Fessenden's request, Alexanderson used a wood core instead of iron for the stationary armature winding since Fessenden anticipated unacceptable hysteresis and eddy-current losses in iron subjected to radio frequencies. The resulting alternator (Fig. 4) with two 12-in-diameter steel rotors was shipped to Fessenden in August 1906. It produced a maximum frequency of about 75 kHz, although the power at that frequency was less than hoped for. Nevertheless, Fessenden was delighted with the performance and was confident that it was a revolutionary innovation in radio.

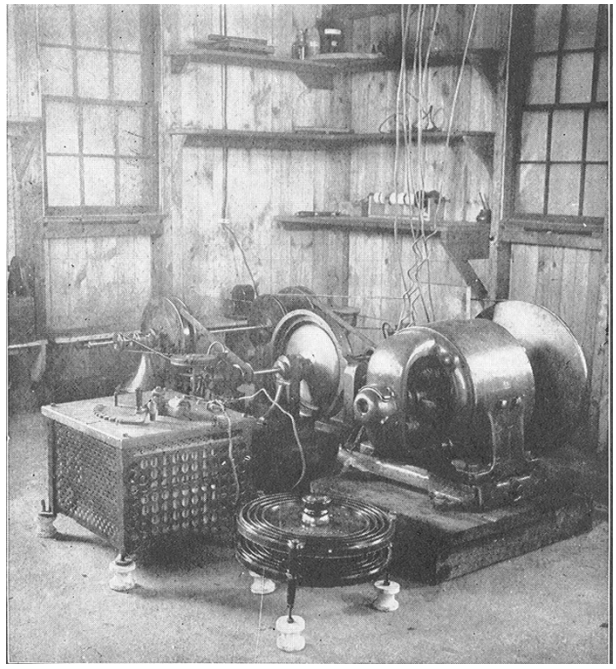

Fig. 4. Radio alternator used at NESCO Station in Brant Rock, MA in 1906 for voice and music broadcasts. [From A. N. Goldsmith, *Radio Telephony* (New York: Wireless Press, 1918).]

VII. December 1906 Demonstrations

The new alternator was used to transmit both speech and music by wireless from Brant Rock to Plymouth, a distance of about 10 mi, in early December 1906. In another experiment, speech was sent to Brant Rock by wire, then to Plymouth by a wireless link, and again relayed over a wire line. During the last week in December 1906, journalists, representatives of the American Telephone & Telegraph Company (AT&T), and other invited guests observed broadcasts of voice and music from the Brant Rock station. Wireless telegraph operators on U.S. Navy and commercial ships in

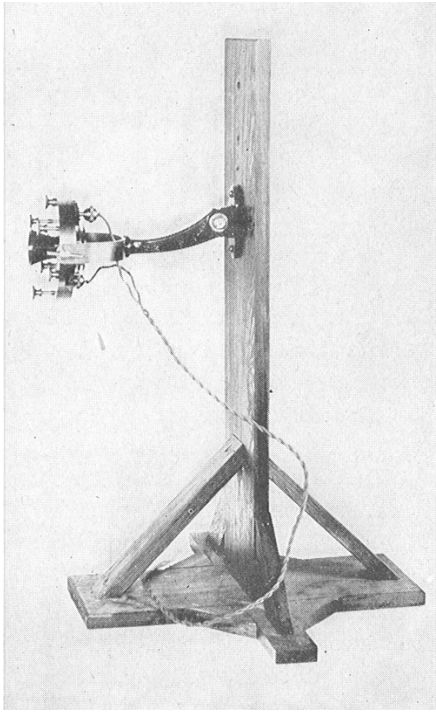

Fig. 5. A high-current water-cooled microphone was a critical component of the transmitter used in the 1906–1907 radio telephony experiments. [From A. N. Goldsmith, *Radio Telephony* (New York: Wireless Press, 1918).]

the vicinity reported picking up the broadcasts. A special microphone (Fig. 5) designed by Fessenden was used for the demonstration and was reported capable of handling up to 375 W for long periods. Negotiations to market the NESCO wireless telephone system to AT&T failed, perhaps due to a financial panic in 1907. Fessenden's tenure with NESCO ended abruptly in January 1911 in a dispute with his Pittsburgh backers, which he blamed on their failure to pay him the amount promised for his patent rights. He filed suit for breach of contract and was awarded a substantial sum for damages. NESCO then went into receivership and ceased to be a significant participant in radio development. Fessenden also essentially ended his involvement in radio except for patent litigation. However, GE continued to develop the radio alternator and was able to produce machines with high-frequency power rating of up to 200 kW by 1918.

VIII. Acoustic Waves in Water

In 1912, Fessenden accepted an offer to become a consulting engineer with the Submarine Signal Company (SSC), Boston, MA. The firm produced underwater communications apparatus, including bells and hydrophones intended to warn ships of navigational hazards. Drawing on his experience in radio engineering, Fessenden designed an electromagnetic transducer, which he called an oscillator in his patent application. His apparatus employed an alternating-current generator as a source of power to produce vibrations in a 22-in diameter circular steel disc which could produce or detect acoustic waves in water. The oscillator was designed to generate about 1.6 kW for maximum output and was supplied with an excitation frequency of 540 Hz. Early in 1913, Fessenden demonstrated that his new system could transmit telegraph messages through several miles of sea water between two boats. He also experimented with using the oscillator for iceberg detection and sounding, using reflections of acoustic waves. The SSC produced the system for use by both the U.S. Navy and the British Navy for submarine telegraphic communication during 1914–1915. After the war, the company began to market a depth sounder or "fathomether" employing the Fessenden oscillator.

In the early 1920s, Fessenden accepted a generous out-of-court settlement involving his radio patents from the Radio Corporation of America and retired to Bermuda. During his last years, he studied ancient accounts of the lost continent of Atlantis and wrote an essay on "The Deluged Civilization of the Caucasus Isthmus." He died 22 July 1932 in Hamilton, Bermuda. Although many of his inventions are no longer used, he was a leading member of the first generation of radio engineers who created the foundation of the electrical communication systems of the present day.

James E. Brittain